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13. ABSTRACT *(Maximum 200 Words)*

This report covers the AASERT grant which is a companion grant to AFOSR 94-0189 of the same title. Over the duration of the grant, support and training were provided for 5 different graduate students and 7 undergraduates. The work concentrated on how 2-D information is built up from the parallel analysis of a set of visual attributes and how this information contacts memory in order to construct 3-D representations of the visual scene. We were specifically interested in the early stages of these processes which may operate under simplified assumptions in order to gain speed. We examined the rapid decomposition of image values into object features (reflectance, transparency, orientation, 3D position) and illumination features (shadows, shading, highlights). We also evaluated the nature of the representation achieved at these early levels and whether the output of each of the many early stages is independently available to higher level processes or only one final "result" gets passed along. Finally, we studied the initial contact between the image contours and memory in recognition.

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AASERT: EARLY SCENE ANALYSIS: RAPID PROCESSING OF CONTOURS, SURFACES, AND OBJECTS IN HUMAN VISION

Summary

This report covers the AASERT grant which is a companion grant to F49620-94-1-0189 of the same title. Over the duration of the grant, support and training were provided for 5 different graduate students and 7 undergraduates. The work concentrated on how 2-D information is built up from the parallel analysis of a set of visual attributes and how this information contacts memory in order to construct 3-D representations of the visual scene. We were specifically interested in the early stages of these processes which may operate under simplified assumptions in order to gain speed. We examined the rapid decomposition of image values into object features (reflectance, transparency, orientation, 3D position) and illumination features (shadows, shading, highlights). We also evaluated the nature of the representation achieved at these early levels and whether the output of each of the many early stages is independently available to higher level processes or only one final "result" gets passed along. Finally, we studied the initial contact between the image contours and memory in recognition.

Research Training Avtivities

Graduate Students. Peter Tse has developed outstanding research skills including programming, and scientific writing. His work over the period of support from AASERT has already established his reputation as a major creative contributor to vision research. He won the prestigeous McDonnell-Pew Fellowship for 3 years and will begin a postdoc at the Max Planck Institute in Tubingen this fall. His training has been a great success. During his period of support, James Intriligator developed several software techniques which are used by many in our lab and his work on attention has been very influential. Alex Holcombe and David Whitney have become strong experimenters and have good potential. Stephen Hau dropped out of graduate school after one semester.

Undergraduates. Our interest in the internal representation of object shape has led us to focus on simple two tone representations of shadowed images. Several undergraduates participated in this project as artists producing stimuli for our priming experiments. They were introduced to various aspects of computer controlled image manipulation and to theories of visual perception and visual memory. One undergraduate (Yuri Ostrovsky) developed new software for us on the Warping function of our DataCube image processor. He was trained in programming techniques for video pipeline processors. Christopher Dye learned about programming and image presentation during his summer assistantship.

Accomplishments / New Findings

Object recognition: positive priming. In our model, recognition starts with an initial, crude 2-D match that selects a "best" prototype to explain the image data. This is followed by more sophisticated 3-D analyses to complete the recognition process. Our first experiment showed a priming effect of contours in recognition even though the contours alone were uniformative for the task. David Whitney has repeated our earlier experiments during using a new set of subjects.

Object models and motion perception. Peter Tse has developed a new theory for apparent motion that relies on parsing each scene into objects before matching takes place. The novel aspect of the work is that the shapes in the first frame of the motion sequence overlap spatially with those in the following frame. This enables Peter to test for principles of shape parsing (continuity, surface similarity, contiguity) that do not come into play in standard apparent motion where the shapes do not overlap. This give us a new tool for understanding image segmentation. This work is published in a recent book (Tse, Cavanagh, & Nakayama, 1998).

Theory of volume. Peter Tse has developed a new theory for the level at which objects are represented in understanding visual scenes. This work is exceptionally novel and important. Rather than depending on relations between image contours or inferring surfaces, Peter shows that the underlying mode of representation is one of volumes or occupied space. Several critical demonstrations show that his formulation accounts for the broad range of image interpretations whereas representations of objects by their contours or surfaces fail. In a very productive year, he has been able to publish four papers on this topic (Tse & Albert, 1998; Tse, 1998a, 1998b) and present four talks (Tse, 1997b; Tse, 1998a; Tse 1998b; Tse & Albert, 1998).

Attention resolution. While supported by this grant James Intrilgator contributed to landmark work on the resolution of attention published in *Nature* and *Trends in Cognitive Science*. He showed that the ultimate limit on performance is not set by the fine detail you can see but rather by the very coarse access you have to that detail.

Time perception. Peter Tse and James Intriligator were also able to demonstrate the intuitive notion of the slowing of time during attention-grabbing events (like a car accident). An attention-grabbing, odd item in a sequence of items appeared to last about 50% longer than than its real duration.

Personnel supported

Personnel on this grant. Graduate students: Peter Tse (3 years, 6 months), David Whitney (8 months), Alex Holcombe (1 year), James Intriligator (2 years), Stephen Hau (4 months). Undergraduates: Christopher Dye (summer research assistant), Jonathan Liu, Derek McKee, Jason Gross, Naima Workman, Sebastian Conley (artists), and Yuri Ostovsky (programmer).

Publications supported by this AASERT grant

He, S., Cavanagh, P., & Intriligator, J. (1996). Attentional resolution and the locus of awareness. *Nature*, **383**, 334-338.

He, S., Cavanagh, P., & Intriligator, J. (1997). Attentional resolution. *Trends in Cognitive Science*, **1**, 115-121.

Tse, P., Cavanagh, P., & Nakayama, K. (1998). The role of parsing in high-level motion processing. In Takeo Watanabe (ed.), *High level motion processing*. (pp. 249-266), Cambridge, MA: MIT Press.

Tse, P. & Albert, M. (1998). Amodal completion in absence of image tangent discontinuities. *Perception*, **27**, 455-464.

Tse, P. (1998). Illusory volumes from conformation. *Perception*, in press.

Tse, P. (1998). Volume completion. *Cognitive Psychology*, in press.

Interactions, conference papers during grant period supported by AASERT grant

*Tse, P., Cavanagh, P. & Nakayama, K. (1995). Line motion occurs after surface parsing. *Investigative Ophthalmology & Visual Science*, **36**, S417.

Tse, P., Cavanagh, P., & Nakayama, K. (1996). The roles of attention in shape change apparent motion. *Investigative Ophthalmology & Visual Science*, **37**, S213.

Tse, P., Intriligator, J., & Cavanagh, P. (1997). Attention distorts the perception of time. *Investigative Ophthalmology & Visual Science*, **38**, S1151.

Tse, P. (1997). Plasmas: A new class of motion-induced brightness illusions. ECVP, Helsinki.

Tse, P. (1997). Volume Completion. OPAM, Psychonomics Meeting, November, Philadelphia.

Holcombe, A. O., Tse, P., Macknik, S., Seiffert, A. E., & Intriligator, J. (1998). Wakes: a new motion-induced brightness illusion. *Investigative Ophthalmology & Visual Science*, **39**, S671

Tse, P. (1998). Volume relatability, volume completion, and illusory volumes. *Investigative Ophthalmology & Visual Science*, **39**, S1132.

Tse, P and Albert, M. (1998). Amodal completion in the absence of image tangent discontinuities. ECVP, Oxford University.

Tse, P. (1998). Volume Completion. Eastern Psychological Association, February, Boston.

Whitney, D. V., Murakami, I., & Cavanagh, P. (1998). Motion extrapolation cannot account for apparent position offset of a flashed disk relative to unpredictable motion. *Investigative Ophthalmology & Visual Science*, **39**, S1075

New discoveries, inventions, or patent disclosures

Discoveries are reported in the progress section above. There were no inventions or patent disclosures during the grant period.

Honors / Awards

None.